EOS Validation Annual Report for Year 2003

Global Validation of EOS-AQUA Land Surface Dynamics Using Data Assimilation

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Summary of the Report

The primary goal of the NASA EOS validation project titled "Global Validation of EOS-AQUA Land Surface Dynamics Using Data Assimilation" is to develop a data assimilation technology to validate the land products generated from the AMSR_E instrument on board the EOS AQUA satellite. These land products include: surface soil moisture, brightness temperatures, surface temperature, and vegetation water content. During the first year (2002) of this project, an Extended Kalman Filter (EKF) data assimilation algorithm was implemented in NASA's Land Data Assimilation System (LDAS) using the MOSAIC land surface model and TRMM Microwave Imager (TMI) soil moisture retrieval data for SGP99 area were successfully assimilated into the LDAS as a proxy for AMSR data, as it was not yet available. In the second year (2003), AMSR_E soil moisture data products were not available or useful because the retrieval algorithm was based on the 6.9GHz channel brightness temperatures that were heavily contaminated by radio frequency interference (RFI). During the second year, we participated in two field experiments to collect ground observational data for validating the satellite retrievals of surface soil moisture. These were the SMEX03 experiment conducted in Chickasha, Oklahoma and the AMSR_Australia experiment conducted in the arid area of central Australia. In addition to the AMSR_E soil moisture validation activity, we have been investigating data assimilation methods for retrieving surface soil moisture from the future HYDROS radar and radiometer observations. Recently, the AMSR_E soil moisture product algorithm development team revised the retrieval algorithm and the AMSR_E soil moisture data become available starting in February 2004. We have processed some of these data and have a preliminary evaluation on the newly generated soil moisture retrievals. Results of the AMSR_E validation activities and the retrieval algorithm investigations have been presented to several national or international conferences and science team meetings. The preliminary evaluation results will also be presented in a forthcoming journal paper. In the last annual report for year 2002, the "Objective of the Project" was presented. This report summarizes major results achieved in year 2003 and activities planned in the last year (2004) of the project.

Project Introduction

Provision of high quality remotely sensed global land surface measurements is a key element of NASA's Earth Science Enterprise Program. However, it is recognized that these data fields will contain uncertainties due to imperfect instrument calibration and inversion algorithms, geophysical noise, representativeness error, communication breakdowns, and other sources. It is therefore essential that the accuracy and credibility of these remotely sensed fields be evaluated for their use in critical research and applications. Data assimilation systems have been used extensively in meteorology to expose significant defects in satellite data processing schemes, technology limits, bias, and noise. Modern data assimilation techniques use relevant prior data and a state-of-the-art computer model to estimate the state of the land surface. For each observation, a background value is derived from the model forecast for comparison. Systematic differences between observations and model predictions can identify systematic error, or identify uncharacteristically large differences in observations. Thus the consistency of the model provides guidance to identify observation problems in a data assimilation context. The "Global Validation of EOS-AQUA Land Surface Dynamics Using Data Assimilation" is to determine the nature and variability of the uncertainties in the selected global soil moisture products via completing the following three tasks:

1) *Soil moisture observation quality monitoring*: use innovative land surface data assimilation techniques to check the quality control, physical consistency, and systematic realism of global EOS-AQUA land observations, in the context of the collaborative, real-time Land Data Assimilation System (LDAS) project. After the proved Kalman Filter data assimilation algorithm is implemented in LDAS, the KF-LDAS system is used to monitor the spatial-temporal AMSR soil moisture observation quality.
2) *Production of land surface soil moisture and snow water observation fields using data assimilation*: use KF-LDAS to extend AMSR-E products in time and space to produce consistent data assimilation land surface fields that are valuable for use in subsequent analysis and application.
3) *Cross validation with in situ and airborne observations*: Selected *in situ* and airborne land surface observations are used as a secondary test of data integrity.

Progress Report

In the following sections, we summarize the project progress and accomplishments, and activity plans for 2004 on each of the three tasks respectively.

Task 1: Soil moisture observation quality monitoring

1.1. Progress and Accomplishments:

Before assimilating satellite observations into models, the quality of the data needs to be checked. The AMSR_E soil moisture data product was generated with an algorithm using the two AMSR C-band (6.9GHz) brightness temperature observations. Because of the heavy RFI contamination, the retrieved soil moisture data were not useful. At the end of 2003, the AMSR_E land product generation team revised the soil moisture algorithm

to only use the AMSR 10.7GHz channels. The new results generated with the algorithm become available in February 2004.

We have processed the daily data for 37 days from Feb 10 to March 17, 2004. Figure 1 shows the retrieved global surface soil moisture for the two days of 2/17 and 2/18/2004. A significant magnitude change of the retrievals is evident from ascending to descending data on 2/17. It might indicate the change of retrieval algorithm. Before the algorithm revision, soil moisture retrievals were much too low to be of scientific use. For other areas they seemed very high (e.g. the Amazon area). After the algorithm revision, the retrievals of most areas are more reasonable, but show less spatial pattern.

AMSR_E Soil Moisture Daily Data Product For Two Days

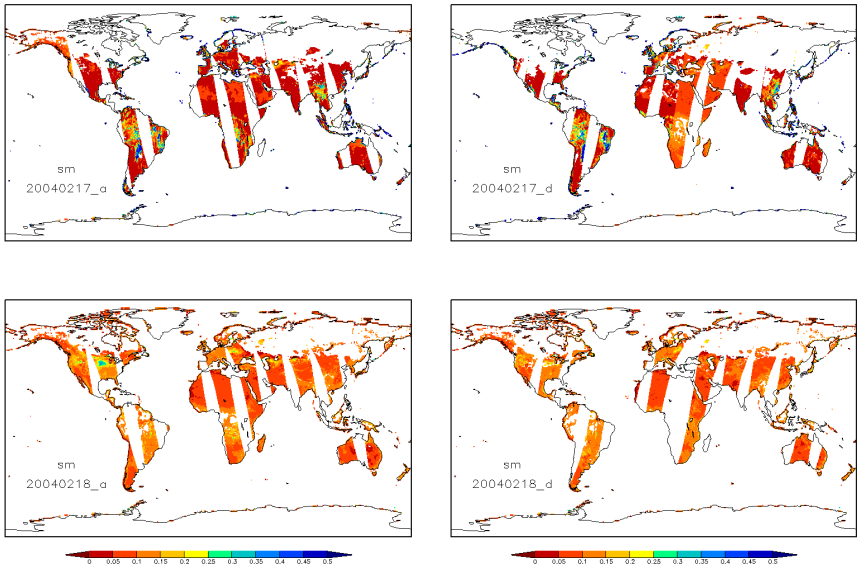

Figure 1. AMSR_E global soil moisture retrievals for two days in February 2004. The significant magnitude change might indicate the algorithm revision of the soil moisture data product.

Three-day composites of these soil moisture retrievals have been obtained by averaging all available retrievals within three day windows, as this is the typical time rate of change for surface soil moisture. Figure 2 are the 4 samples of the 12 days from 2/13 to 2/24/2004. The algorithm transition is also evident in these composites. Again the less heterogeneity of the new results after the algorithm revision may be a defect of the data product.

In order to understand the overall quality of the soil moisture retrieval data set, we have run NASA's Global Land Data Assimilation System using the MOSAIC land surface model forced by ECMWF's reanalysis data at 2 by 2.5 degree resolution for the globe for 15 yeas from 1979 to 1993. The monthly averages of this simulation are computed and used as surface soil moisture climatology. Figure 3 displays the global distribution of surface soil moisture climatology for the Month 2 (February) and 3 (March). An intercomparison between the AMSR_E soil moisture retrievals and the GLDAS soil moisture climatology is demonstrated in Figure 4.

AMSR_E Soil Moisture Three-Day Composites For 12 Days

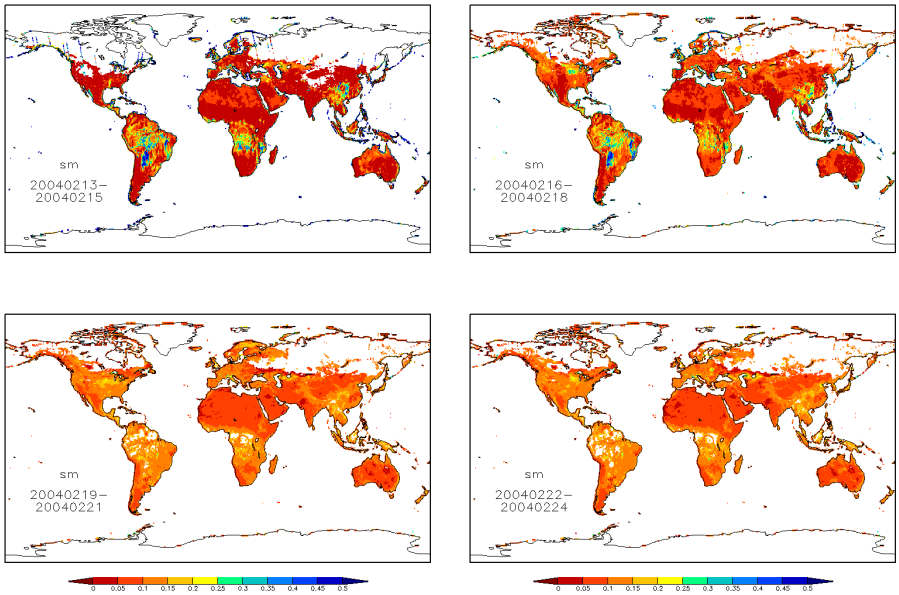

Figure 2. Three-day composites of AMSR_E soil moisture retrievals for 12 days from 2/13 to 2/24/2004.

GLDAS Soil Moisture Climatology From 1979 to 1993

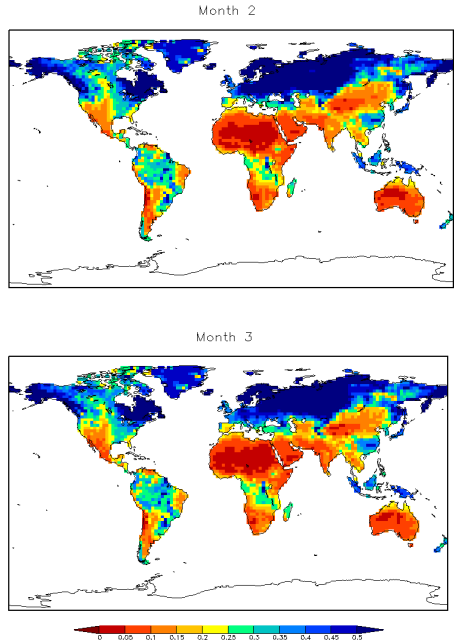

Figure 3. Soil moisture climatology from 1979 to 1993 simulated by NASA's Global Land Data Assimilation System (GLDAS) using the Mosaic model and the ECMWF reanalysis data as forcing. (Matt Rodell provided GLDAS simulation data)

Soil Moisture Difference Between AMSR_E Retrievals and GLDAS Climatology

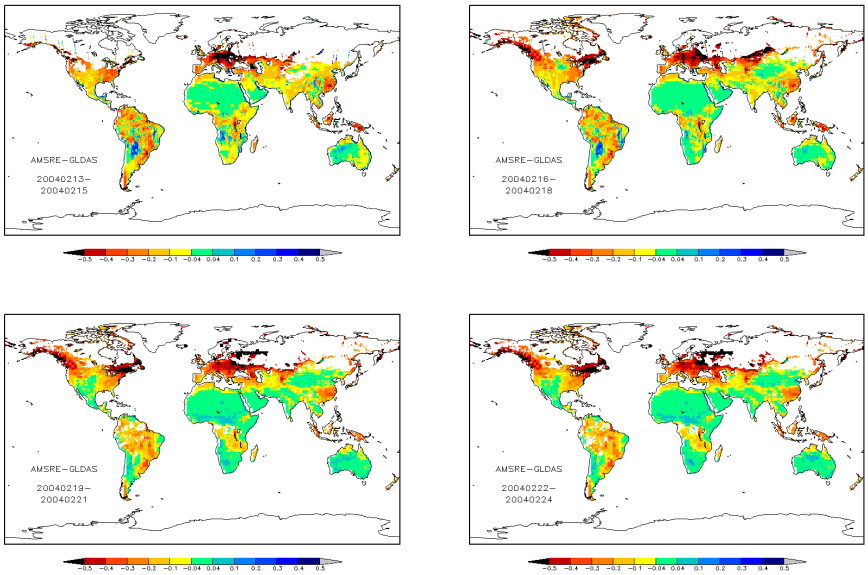

Figure 4. Intercomparison between the AMSR_E soil moisture retrievals and the model simulated soil moisture climatology from NASA's Global Land Data Assimilation System displayed in Figure 3. Comparing with the simulated climatology, the AMSR_E soil moisture retrievals are significantly underestimated for most of the areas in the globe.

Publication and presentation list:

Zhan, X. and P.R. Houser. 2004. A Preliminary Evaluation of the AMSR_E Soil Moisture Data Products Against Field Observations and Model Simulations. In preparation for *Journal of Hydrometeorology*.

1.2. Work Plan for the Year 2004:

More complete intercomparison between global soil moisture data products will be conducted. The causes for the difference between the data products will be identified and presented to the AMSR_E soil moisture data developers and users. A manuscript on the results from the data quality investigation is in preparation for publication.

1.3. Data Management and Archive:

This task will produce quality checked AMSR_E land products and QC statistics. These intermediate land products will be stored in-house and analyzed in Task 2 for further validation with data assimilation

Task 2: Production of land surface soil moisture observation fields using data assimilation

2.1. Progress and Accomplishments:

Under this task, major efforts were put into the investigation of data assimilation methods for retrieving soil moisture from the L-band radar and radiometer observations of the future

HYDROS mission, as a proxy for unavailable AMSR soil moisture retrievals. As an effort of the HYDROS science team, a HYDROS Observing System Simulation Study (OSSE) was conducted. Our objective was to develop an algorithm to accurately retrieve median resolution surface soil moisture by effectively combining the fine resolution radar backscatter and coarse resolution radiometer brightness temperature observations. An Extended Kalman Filter algorithm has been successfully implemented for the purpose. Figure 5 is one of the soil moisture retrieval results by the EKF algorithm. The EKF retrieval algorithm using both HYDROS radar and radiometer observations is shown to have advantages over the iterative inversion methods using either radiometer brightness temperature or radar backscatters.

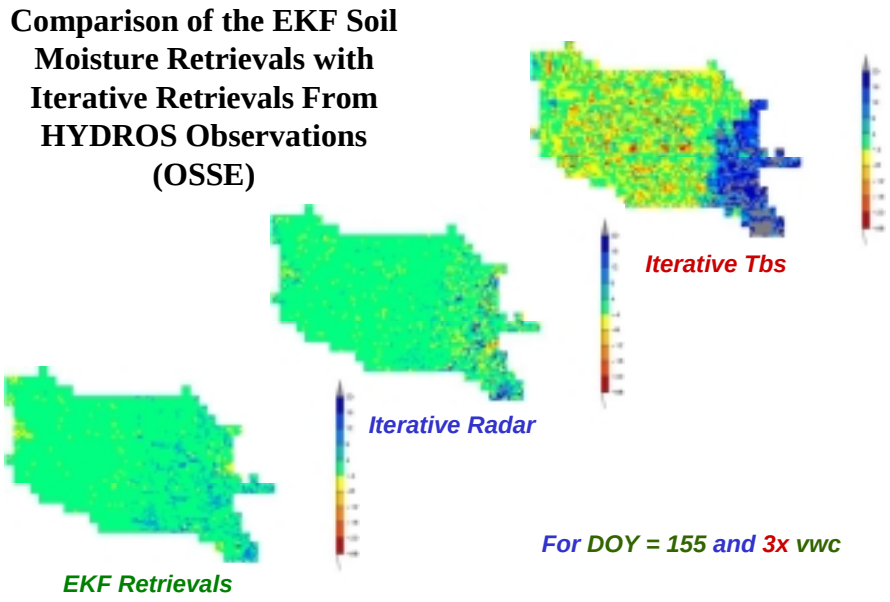

Figure 5. Results of the Extended Kalman Filter soil moisture retrievals compared with the results from the iterative inversion methods using either HYDROS radiometer brightness temperatures or radar backscatters.

Publication and presentation list:

Zhan, X., P.R. Houser, J.K. Walker, D. Entekhabi, E. Njoku and W. Crow. Retrieving surface soil moisture from HYDROS brightness temperature and radar backscatter data using Kalman Filter data assimilation techniques. Presentations to HYDROS Science Team meetings. JPL, Pasadena, CA. 2003

Zhan, X., P.R. Houser, J.K. Entin, J.P. Walker and R.H. Reichle. 2004. Implementation of the Extended Kalman Filter in NASA's Land Data Assimilation System for soil moisture data assimilation. In preparation for *Journal of Hydrometeorology*.

Zhan, X., P.R. Houser, J.K. Walker, D. Entekhabi, E. Njoku and W. Crow. 2004. Retrieving surface soil moisture from HYDROS brightness temperature and radar backscatter data using Kalman Filter data assimilation techniqu. In preparation for *IEEE Transactions for Geoscience and Remote Sensing*.

2.2. Work Plan for Next Year:

When more stable AMSR_E soil moisture data files are collected, we will process them into the file format matching NASA's Global Land Data Assimilation System (GLDAS). Using the Kalman Filter data assimilation algorithm already implemented in GLDAS, an assimilated soil moisture data product will be generated at the global scale.

2.3. Data Management and Archive:

Data assimilation output from Task 2 will be stored in-house. After further validation with in situ and airborne observations, the data assimilation results will be submitted to the National Snow and Ice Data Center (NSIDC) for archive

Task 3: Cross validation with in situ and airborne observations

3.1. Progress and Accomplishments:

We have participated in two field experiments. One is the NASA sponsored Soil Moisture Experiment (SMEX03) conducted in Chickasha, Oklahoma in July 2003. The other was conducted in the vast arid area of central Australia from September 19 to October 15, 2004. Details of SMEX03 are in http://hydrolab.arsusda.gov/smex03/. Figure 6 shows a typical soil sampling site and equipments we used in the Australia field experiment and Figure 7 demonstrates some results from the sampling.

Publication and presentation list:

Walker, J. P., Grayson, R. B., Panciera, R., Zhan, X., and Houser, P. R., 2003. AMSR-E Soil Moisture Validation Efforts in the Australian Arid Zone, *EOS, Transactions American Geophysical Union*, 84(46), Fall Meeting Supplement, Abstract H22E-05.

3.2. Work Plan for Next Year:

A field experiment called SMEX-NAME will be conducted in Tucson, AZ and a Mexico site in the summer of 2004. We plan to participate in the fieldwork. We will use the field observation data to cross validate the AMSR_E soil moisture retrievals and the assimilated soil moisture planned in Task 2.

3.3. Data Management and Archive:

Data assimilation results from Task 2 will be cross-validated with in situ and airborne observations. Output will be submitted to NSIDC for archive.

Figure 6. A typical site and equipments for the soil sampling during the Australia AMSR_E validation field experiment conducted in the vast arid area of central Australia from September 19 to October 16, 2003.

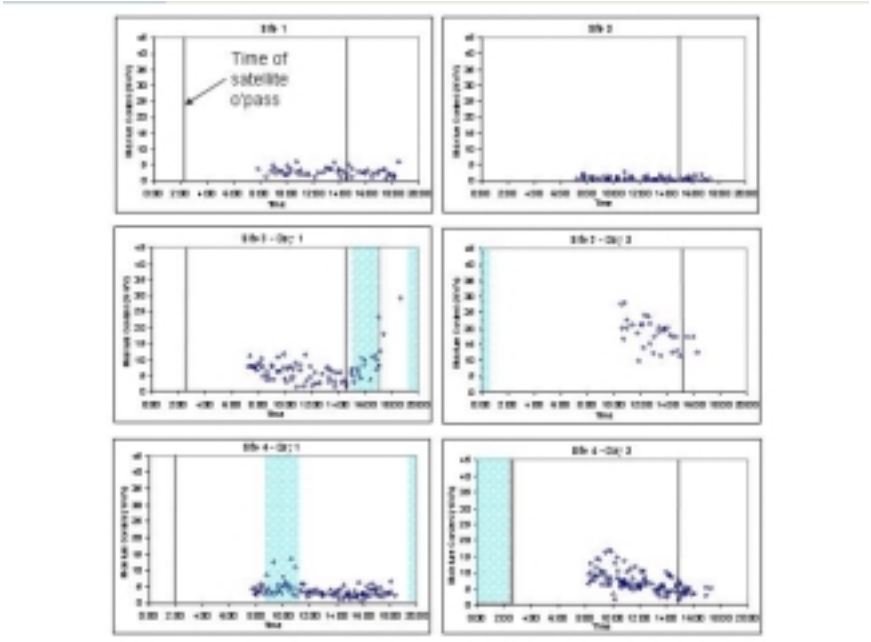

Figure 7. Soil moisture observations obtained from the Australia AMSR_E validation field experiments conducted in the vast arid area of central Australia from September 19 to October 16, 2003.